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RESEARCH ARTICLE

The effectiveness of central auditory processing rehabilitation program on speech reception in noise and dichotic listening in dyslexic students

Masumeh Ghasemi[1*], Saeed Hassanzadeh[1], Mohsen Shokoohi-Yekta[1], Gholamali Afrooz[1], Ali Akbar Tahaei[2], Valiollah Farzad[3]

[1]- Department of Psychology and Education of Exceptional Children, Faculty of Psychology and Education, University of Tehran, Tehran, Iran

[2]- Department of Audiology, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

[3]- Department of Psychology, Faculty of Psychology and Educational Sciences, Kharazmi University, Tehran, Iran

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Abstract

Background and Aim: Auditory processing disorder and dyslexia have been reported by many studies as having high comorbidity. The purpose of the study was to investigate the effectiveness of central auditory processing rehabilitation program on speech reception in noise and dichotic listening in dyslexic students. The research was quasi-experimental, including a pretest, posttest and a control group.

Methods: The population involved dyslexic elementary school students, studying in a learning disorder center in Tehran. Using convenience sampling method, 30 dyslexic students with central auditory processing disorder (CAPD) were selected and put into experimental and control groups. Speech in noise (SIN) test and dichotic digits test (DDT) were conducted in the pretest for all students. Central auditory processing rehabilitation program was designed in 12 steps with different practices. The experimental group received 15 sessions of central auditory processing rehabilitation program. Speech in noise test and dichotic digits tests were conducted again in the posttest for all students.

Results: The data analysis using repeated measures multi-variable analysis of variance indicated a significant difference among the mean scores of speech in noise and dichotic digits tests in the experimental and control groups ($p<0.05$). The experimental group had gained better scores.

Conclusion: According to the results, the central auditory processing disorder rehabilitation program significantly enhanced speech reception in noise and dichotic listening in the dyslexic students.

Keywords: Central auditory processing; dyslexia; speech reception in noise; dichotic listening

[*] **Corresponding author:** Department of Psychology and Education of Exceptional Children, Faculty of Psychology and Education, University of Tehran, Jalal Al-e-Ahmad Ave., Tehran, 1445983861, Iran. Tel: 009821- 61117415,
E-mail: mahnaz.ghasemi@gmail.com

Introduction

Developmental dyslexia is a disorder in which the reading level differs with the child's intelligence and this is while the child has had adequate reading education. In other words, a dyslexic is a person who fails to read, despite being intelligent or educated or despite having sociocultural opportunities. This disorder runs on in

the person's life and reading problem is just one of its indications [1,2]. Having problems in spelling, phonological awareness, rapid naming, and verbal short-term memory are among these difficulties [3,4].

Of the many famous etiological theories in developmental dyslexia, one can name central auditory processing disorder theory and phonological deficit theory [5].

Auditory processing refers to analyzing, coding, storing and organizing the acoustic features of the auditory signals. In other words, auditory processing is the capability of the central nervous system in using the auditory data. The central nervous system discovers the general format of the signal and the rapid spectral changes, which is a characteristic of speech and encodes the acoustic features of verbal sounds such as frequency, intensity, temporal aspect, and the duration of such sounds. This information is transferred through the nervous impulses [6].

The central auditory processing disorder (CAPD) theory is based on this belief that dyslexia is rooted in understanding short and rapidly-changing sounds. In this theory, the direct cause of dyslexia is regarded as phonological deficit and reading problem. The research results show that the dyslexic children have weak performances in some auditory tests such as frequency discrimination and temporal sequence tests, and they also have weaker perceptions of phonological differences [7].

Also, the children with learning disability usually complain about speech reception in noise. One of the most conspicuous characteristics of these children is their problem in degraded auditory situations [8]. These children face highly challenging auditory situations and environments after entering the elementary school and since in school, a huge amount of auditory information is given, their learning level in such circumstances declines [9].

In order to investigate the relations between auditory processing and dyslexia, many studies have been conducted, and the results of most of them indicated a connection between these two disorders [10-13].

Moreover, the dyslexic students have some problems in phonological memory and phonological awareness and do poorly in verbal short-term memory tests. In any case, considering such issues, generally the phonological processing deficits have been regarded as the core deficit in dyslexia [1,2]. However, another group of experts call the phonological deficit theory into question. In fact, they do not deny phonological processing deficit and its role in dyslexia, rather they suggest that phonological deficit is produced secondarily and it is the auditory processing disorder that causes the phonological deficits. In this regard, once again the auditory processing disorder theory is proposed [10].

The facts that the CAPD is a sign of dyslexia, or such disorder can be defined in a separate profile, regarded as a disorder that has high comorbidity with dyslexia, are still unresolved dilemmas [14].

One of the most important disorders whose high comorbidity with CAPD has been confirmed in various studies, is learning disability [12]. The prevalence rate of central auditory processing disorder in elementary school children is 3 percent and in children with learning disability is 30-50 percent, according to the studies [14]. The high comorbidity of central auditory processing disorder and learning disability (LD), indicates the existence of dyslexia in most of the children with learning disability, while highlighting the importance of reading in early years of elementary education, and also clearly demonstrates that focusing on CAPD and its evaluation and treatment in the children with dyslexia are very significant.

The interventional approaches in case of central auditory processing disorder are classified into three categories: environmental modifications, compensational approaches and direct skills rehabilitation [15].

Environmental modifications consist of issues like modifying the acoustic environment of the classrooms, and the compensational approaches include some approaches like using auditory aids (e.g. FM systems). In direct skills rehabilitation, the empowering of involved skills in hearing activity is directly focused upon, and a

series of tasks are done in order to create or reinforce such skills. The function of these tasks is similar to auditory training tasks.

For many years, auditory training has been officially and non-officially regarded as the main rehabilitation approach for the children with CAPD [16,17]. The results of many studies show that such training has been effective in CAPD [18,19].

Various rehabilitation programs have been designed for the auditory training of the CAPD and their effectiveness has also been studied in different languages. Famous programs such as Fast ForWord (FFW) and earobics have been used in many countries while their effectiveness has been confirmed in various studies [17]. Yet, no Persian version of such programs is available.

In our country, the common therapeutic programs used in rehabilitation clinics and learning disability centers normally include the non-official educational approaches, and there is no comprehensive, planned and unanimous program for rehabilitating the CAPD. The studies done in the country also have investigated the effectiveness of one or more auditory tasks on the improvement of central auditory processing disorder, in all cases [20,21]. In the present study we tried to design a comprehensive program which encompasses a complete series of auditory tasks for Persian language and based on Iranian culture, which shall be executed for many dyslexic children with CAPD, and then we investigated the effect of this program on speech perception in noise and dichotic hearing of the mentioned children.

Methods

This study was an applied one in case of purpose, and in case of method, it was a quasi-experimental with pretest, posttest and a control group. The central auditory processing rehabilitation program was regarded as the independent variable, while the speech perception in noise and dichotic hearing were considered as dependent ones.

The population of the study consisted of the students from second, third and fourth elementary school grades, with dyslexia diagnosis who were studying in learning disabilities centers of Tehran, among which a group of students were selected using convenience sampling method. Considering the fact that in quasi-experimental studies, 15 subjects would suffice for each group [22], the selected 30 students were put in similar groups based on education levels, namely in two experimental and control groups. One of the control group subjects did not attend in posttest, and finally 29 subjects were involved in the study.

Instruments

Inclusion-criteria sheet

This sheet was prepared for recording the demographic analysis results of the subjects such as their education level and the test date, the child's intelligence status (it was necessary that the IQ level of the subjects be 85 or higher in Wechsler test), handedness (the left-handed would be omitted from the research), the possible emotional problems, learning difficulties, previous record of repetitive ear infection and hearing reduction, sight problems and also the previous record of brain damages, neurological disorders, and also the dyslexia criteria according to the Diagnostic and Statistical Manual for Mental Disorder (DSM-V) by the researcher, which was filled out by studying the child's profile in the learning disability centers and interviewing the parents.

Fisher's auditory problems checklist

Fisher's auditory problems checklist was developed in 1976 as an instrument for screening the children with central auditory processing disorder. This checklist consists of 25 items that can be completed by parents, teachers or the pathologists of speech and language. This instrument checks the central auditory processing skills in 13 areas such as acuity, attention, attention span, detection of the original sound from noise, discrimination, short-term memory, long-term memory, sequential memory, speech and language problems, auditory-visual integration, motivation and performance [23]. The least score in this checklist is 0 and the highest one is 100.

Fisher has suggested the cut-off score of 72 as the indication score for the children at risk of central auditory processing disorder. Hence, if a child who scored at or below this value, would be referred for further diagnostic testing. In order to test the validity of Fisher's auditory problems checklist and in order to screen the CAPD, this instrument is given to 5 experts of the field, and they were asked to comment on each of the checklist items in a three-score questionnaire (with agree, neutral, and disagree scales). Each of the items that have 80% of agreement (4 out of 5) will remain in the checklist, otherwise it will be omitted. The reliability of the questionnaire was also confirmed using the test-retest method and Cronbach's alpha test as 88%.

Speech perception in noise test

Speech perception in noise and competitive speech are placed in this category of tests. The primary applications of this test in Sinha's studies go back to 1959 [14]. In this test, 25 monosyllable words are presented to child's both ears (provided that the disparity of hearing threshold of right and left ears in case of speech frequencies of 500, 1000, 2000, 4000 Hz be no more than 5 dB). The words are articulated once in silence, and another time in the presence of white noise and in signal to noise ratio (SNR) of 6. For each correct perception and repetition of each word, four scores are given to the child. The scores difference between the test steps forms his/her "difference score" which is used for evaluation of the child's speech perception in noise skill [24]. The validity of the English version of the test has been confirmed in many studies [13]. However, in the case of the Persian version of the test, the experts' comments were used for "speech in noise test" validity confirmation. The Persian version of the test was given to 5 audiologists and its content validity was also verified. The validity test was done by test-retest method with the correlation coefficient of 0.86.

Dichotic digits test

This test is a verbal dichotic one which uses indirect form of answering and evaluates the hearer's competence in case of processing the different information, which is given binaurally at the same time. In this test, two auditory stimuli are simultaneously presented to the right and left ears separately, and then the subject is asked to repeat what he has heard with both ears. The test materials are numbers 1 to 10, except 4 (whose Persian equivalent is *cha-har* which has two syllables). Each part of the test is made of four numbers. Two numbers are presented to the right ear and two numbers are articulated to the left ear and the child is told to repeat all the numbers he/she has heard [25,26]. Totally, 25 pairs of numbers are said to the right ear and 25 pairs of numbers are presented to the left ear as well. The least and the highest scores for each ear are 0 and 100. In order to determine the validity of the test, split half and test-retest methods and validity coefficients calculated are 0.7 and 0.85, respectively [23]. Since this test, has no cultural and linguistic value and it is made exactly based on the original test, there is no need for validity and reliability determination in Persian.

Dyslexia screening test

This test has been designed in Isfahan University, for screening dyslexia in the elementary level. The main part of the test is made of a 100-word text and four questions of reading comprehension. The student is asked to read aloud a text and afterwards, he/she would orally answer the reading comprehension questions which are open-ended. If the student could correctly read less than 90% of the words, and his/her reading comprehension score is less than 50%, he will be classified in incapable reading level (sub-reader). The students, who are in the incapable level, can be regarded as the student with reading problem. This test has been done conducted in elementary schools from grades 1 to 5 in Isfahan, central Iran. The correlation of the scores was the accuracy and speed of reading with high total score. The test validity value was 0.77 based on Cronbach's alpha test and also there was a significant mean scores difference between the dyslexic and non-dyslexic groups [28].

Rehabilitation procedure

In the first step of the present study, the central auditory processing rehabilitation program was designed and prepared according to the following stages. First, the theoretical framework of the program was studied. Then, the literature and the current programs were investigated so that the effective educational factors are identified and also the weaknesses and strengths of the common auditory rehabilitation programs were discussed. Most of the official auditory training programs were not comprehensive and each of them just covered a part of the problem. For instance, some programs focused on the linguistic issues such as the phonological awareness and speech in noise perception, while some others considered the various auditory discriminations such as frequency, intensity, and duration discriminations, and there were some studies which targeted the dichotic hearing reinforcement and memory and attention [15-18]. Therefore, a list of official valid programs' tasks was prepared and a series of non-official auditory training tasks were added to it, so that a rather comprehensive collection was designed. That part of the tasks, which had cultural and linguistic values, were designed based on the Iranian culture and Persian language. The words, sentences and texts used in the study as the instruments, were selected from the elementary school Persian language books, suitable for different academic levels. Also, the theme of the stories used was adjusted according to the level of the child and also based on the events that can occur between an Iranian child and his/her family. Most of the tasks were designed in two states of silence and with background noise. In this program, a white noise with 20-50 dB was used in different stages of the training. Afterwards, the needs assessment questionnaire was designed and given to 20 experts who have been in touch with the target society and also the ones who are active in rehabilitation and educational affairs, so that their ideas on the current status and the essential needs of the field were discussed and considered in the program. These experts included speech and language pathologists, auditory training experts and special teachers of learning disability centers. After analyzing the results of the previous steps and using the experts' ideas, an early edition of the program was produced. Then, the program was investigated in case of face and content validity. Hence, the produced early version of the program was given to five experts of the fields. Two of them were audiologists, two were speech and language pathologist, and one expert was a specialist of auditory training. A table with three-score Likert scale was prepared these experts were asked to comment on each step of the program and the tasks of each step, with "agree, neutral, and disagree" choices. Also, they were asked to write their ideas and suggestions in details about the program and mention if the program seems to have executive barriers. Each step or tasks would remain in the program if four of the five experts agreed with that, otherwise it was omitted. Then the prepared program was executed for three dyslexic children as a preliminary cases for 10 sessions, and the administration barriers were reviewed by the researcher, and according to the feedbacks of the pilot execution of the program, the problems of the early edition were eradicated and the original version of the program was produced.

The structure of central auditory processing rehabilitation program is made of 12 steps, while each step involves several tasks. The order of the steps is from easy to difficult and also in each step, the tasks go from easy to difficult, as far as possible. The number of sessions that the therapist spends in each step or the number of steps that are taken in each session depend on many factors such as the individual capacities of the child, the areas in which he/she has problem, the acuity of his/her problem in each area, and his/her interest and motivation for doing the tasks. The steps of central auditory processing rehabilitation program are as follows:

Step 1: detection of subliminal auditory stimuli
Step 2: frequency discrimination
Step 3: syllabic discrimination
Step 4: durational discrimination
Step 5: intensity discrimination
Step 6: localization of the auditory stimuli (verbal and nonverbal)

Step 7: reinforcing the nonverbal auditory memory
Step 8: reinforcing the verbal auditory memory (direct and inverse)
Step 9: shared reading
Step 10: reinforcing the phonological awareness
Step 11: active listening (productive-lexical-grammatical)
Step 12: reinforcing binaural hearing

Having prepared the program, the researcher visited the learning disability centers, after getting a letter of introduction from the office of education in Tehran, and asked the related officials to refer the students of grades two, three and four with dyslexia diagnosis to participate in the research in a clinic that was considered for this purpose. As the students and their parents came into the clinic, first their written consent to participate in the research was taken. Then, the necessary evaluations for checking the prerequisites in order to take part in the study were done. The procedure was in this way that initially the student would undergo otoscopy by an audiologist. Each of children who were diagnosed of cerumen impaction or other damages related to tympanic membrane and external or middle ear, would be referred for medical proceedings and was omitted from the study process. In the next step, pure tone audiometry was conducted in common audiometry frequencies (250-8000 Hz) for the students, and the students that had less than 20 dB in case of the mean threshold pure tones, would qualify for the next step. Then, the study entry criteria control papers were completed for the students. In the next step, the parents of the students who had no problem for entering the study would complete Fisher's auditory problems checklist. If the students'' score was 72 or below, they would be diagnosed of being at the risk of CAPD and they would be assessed with central auditory processing tests. If in both tests, they were two standard deviations or more, lower than the population mean, or in one of the test, they were 3 standard deviations or more, lower than the population mean, they would undergo the dyslexia screening test. In this step, the students who got 90 scores or less, in the test were selected. This procedure continued up to reaching the limit of the sample volume, and finally 30 dyslexic students with CAPD were chosen, among which 15 were put in the experimental groups, and 15 were grouped in the control. The students of both groups were matched according to education level and grade.

Next, the experimental group was trained with central auditory processing rehabilitation program. The program was done for each student individually, in three 45-minute sessions in a week, for five weeks by the therapist of the center. Thus, for each student of the experimental group, 15 sessions of individual therapy of central auditory processing rehabilitation was conducted. If for any reason, a student was absent in the therapy sessions, in the first possible time, a make-up therapy session would be held for him/her, so that none of the students attend less than 15 therapy sessions.

Before commencing the research program, the parents of both control and experimental groups were asked to avoid any other rehabilitation and therapy programs for their children, during the program. After finishing the therapy sessions, speech in noise perception and dichotic digits tests were conducted for both groups. One student from the control group did not attend in the posttest and was excluded from the study.

Also, in order to investigate the reliability of the central auditory processing rehabilitation program effects, the two mentioned tests were done, after five weeks from the posttest for all the students of control and experimental groups, and the results were recorded.

In order to investigate the effectiveness of the program and also for answering the research questions, first the data, mean and the standard deviation of the studied variables were described and then for answering the research questions, a repeated measures two-variable analysis of variance on a factor, was used.

Results

In this part, firstly the descriptive features (mean and standard deviation) of the dependent variables were presented in three measurement steps including pretest, posttest and follow-up

Table 1. Mean (standard deviation) difference scores of speech perception in noise test in control and experimental groups

	Mean (SD) scores		
Group	**Pretest**	**Posttest**	**Follow-up**
Experimental	51.47 (8.26)	26.67 (7.80)	24.27 (8.61)
Control	46.86 (5.06)	43.71 (7.76)	40.86 (7.22)

for the control and experimental groups.

Mean difference scores of the speech perception in noise test in the experimental group in posttest have reduced compared to the control group (Table 1, Fig. 1). As it was mentioned earlier, the less the difference score is in the speech perception in noise, the better the speech perception in noise will be.

Mean scores of dichotic digits test (DDT) of right and left ears have increased in the experimental group, compared to the control group in the posttest (Table 2, Figures 2, 3).

In order to answer this question that what kind of impact the central auditory processing rehabilitation program has on the speech perception in noise of dyslexic students, we used a mixed and repeated measures analysis of variance (one inside the subjects: the intervention amount in three times and one among the subjects:

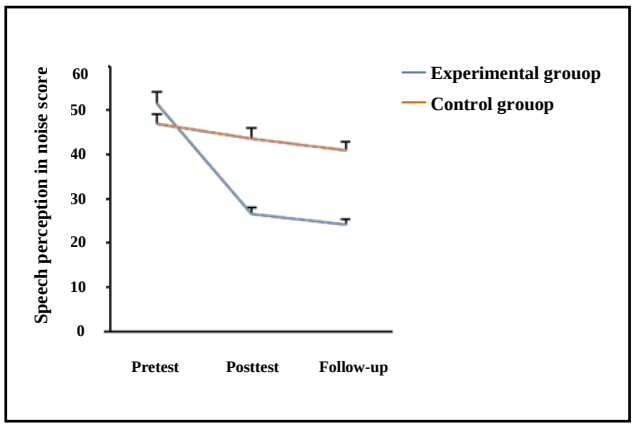

Fig. 1. Mean difference scores in speech perception in noise test in control and experimental grouops.

experimental and control groups), considering the mean difference scores of speech perception in noise test (score difference of speech perception in noise and silence), existence of experimental and control groups and having three measurement stages.

The two hypotheses, data normality, and homogeneity of variances were analyzed. The normality test by means of Kolmogorov-Smirnov test showed that all the data of the presented variables are normal. Also the variables variance homogeneity test and Mauchly's sphericity test, which was another assumption of the repeated measure multivariate analysis of variance, were conducted. All the assumptions were supported.

In order to compare the scores of the groups in posttest and considering their difference in pretest, repeated measures multivariate analysis of variance was used. This test was focused on studying the existence of significance difference between the groups, while considering all the inserted variables first and then it tested every single variable.

The results of repeated measures multivariate analysis of variance for the group ($F_{25\text{-}3}$=8.6, $p<0.01$, η_P^2=0.51), for the time difference source ($F_{22\text{-}6}$=48.59, $p<0.01$, η_P^2=0.93) and the time difference source and group interaction ($F_{22\text{-}6}$=25.58, $p<0.01$, η_P^2=0.87) show that there is a significant difference in at least one of the dependent variables. Also, for determining the significance of each test, one-way analysis of variance with measures was done.

The significance levels show that the effect source related to time is significant in case of all the auditory processing variables ($p<0.05$). This means that in auditory processing variables, there is a difference among the three measurement steps, that is, the pretest, posttest and follow-up. Moreover, in the time and group interaction also the test is significant ($p<0.05$). In this regard, we can say that in the interaction of the two effect sources of the group and time, there is a difference in all the variables between the two groups and in the three steps, in such a way that the mean results show the auditory processing variables have improved. In addition, the partial eta squared (η_P^2), which shows the

Table 2. Mean (standard deviation) of dichotic digits test for the right and left ears in control and experimental groups

Ear		Mean (SD) scores		
		Pretest	**Posttest**	**Follow-up**
Right	**Experimental**	65 (6.31)	75.6 (6.28)	76.3 (5.89)
	Control	64.3 (4.88)	66.4 (5.03)	66.9 (5.06)
Left	**Experimental**	55.2 (6.17)	65.1 (4.52)	65.9 (4.30)
	Control	54.9 (4.13)	55.7 (4.21)	56.7 (4.12)

effectiveness strength, has been presented for the research variables in the two effect sources. The effectiveness strength for the speech in noise test, dichotic test of the right ear, and dichotic test of the left ear in the time effect resource are 0.87, 0.80 and 0.77 respectively; while that value in case of time effect resource and group are in order, 0.77, 0.69 and 0.66. Thus, the null hypothesis saying that there is no difference between the experimental and control groups is rejected and the alternative hypothesis which indicates the auditory processing improvement in both speech perception in noise and dichotic hearing in the experimental group is supported. Considering the fact in the follow-up tests for each of the three tests, the difference between the pretest and posttest, pretest and follow-up, and posttest and follow-up are significant, the impacts' consistency of the central auditory processing rehabilitation program are confirmed.

Discussion

The present research was done with the aim of investigating the effectiveness of the central auditory processing rehabilitation program on speech in noise perception and dichotic hearing of dyslexic students. The analysis of the results indicated that there are significant differences among the scores of dichotic digits test of both ears and speech perception in noise test of experimental and control group in case of posttest and the experimental group have scored better in the posttest. Also, analyzing the subtests results in the follow-up, confirmed the better scoring of the experimental groups, once again.

The central auditory processing rehabilitation program reinforces the direct auditory skill in many steps. Hence, it is not beyond expectation that the central auditory processing status is improved. Almost all of the various tasks are done in the different steps of the program in the presence of a noise, which can enhance the skill of speech perception in noise. Since speech in noise perception is one of the main problems of dyslexic children with central auditory processing disorder, improving such aspect of auditory processing can facilitate the auditory approach for these students –which is the most important approach of learning in the schools –and also it can prevent dyslexia and the related problems.

Furthermore, in other steps of the program, the auditory attention is directly reinforced with the goals of frequency, syllabic, durational and acuity discrimination. Besides, many of these tasks and steps are done in the presence of a noise which can also improve the speech perception in noise, while enhancing the auditory processing in competitive signals and in difficult auditory situations, which finally leads to the better performance in central auditory processing tests.

In step 11 of the program, in which the active listening is focused upon, the auditory attention in various linguistic categories such as productive, lexical and grammatical is reinforced and

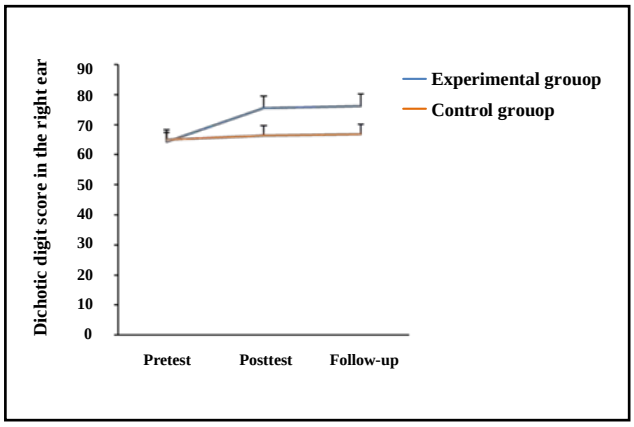

Fig. 2. Mean scores of dichotic digits test of right ear in control and experimental groups.

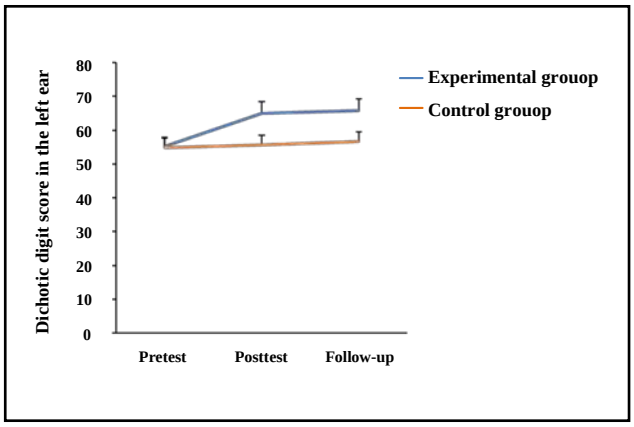

Fig. 3. Mean scores of dichotic digits test of left ear in control and experimental groups.

the improvement of auditory attention can affect and improve the other auditory processing aspects.

In step 12 of the program of central auditory processing rehabilitation, the binaural hearing is reinforced. The tasks which need quick intrahemispheric transference from the corpus callosum are used for children with dichotic combination disorder or dichotic hearing discrimination deficit, and these tasks increase the interaction of the two hemispheres and reinforce the dichotic hearing [29]. Dichotic hearing reinforcement improves the individual's performance in dichotic digits test, which assesses the hearing of both ears. Dichotic hearing reinforcement is one of the main tasks of official and authentic programs whose effectiveness on central auditory processing has been confirmed and is always used as an unofficial task by the therapists, in clinics [30].

There are many studies that confirm the effect of auditory training programs on the central auditory processing. For instance, the studies show that the children that are trained with Fast ForWord (FFW) program or earobics program with the aim of central auditory processing improvement, show some aspects of progress after finishing the therapy course in auditory processing tests [31]. However, there are few cases of research that do not confirm the central auditory processing improvement after the auditory training programs [32]. In any case, the results of most studies are compatible with the results of the present study.

Also, some studies show that the children with central auditory processing disorder considerably progress in speech perception in noise, after working with FFW computer auditory training software, which is one of the most famous auditory training programs. Since, speech perception in noise is one of the aspects of auditory processing, we can say that these programs can improve the central auditory processing and the results of this research are compatible with those of other studies in this field [33-35].

In the process of conducting this research we faced some limitations as well. Using convenience sampling method and the impossibility of doing random sampling was one of the most important limitations of this research which led us to be more cautious while generalizing the results to larger populations. Another limitation of this research was doing the tests in three stages of pretest, posttest and follow-up by the researcher, which may bring about biased decision-making. In this research, the subjects' parents were asked to strongly avoid participating in any other therapeutic program, during the five-week intervention course and also five weeks from the follow-up. We cannot be certain that this thing happened completely. Because of low

sample size, matching of the experimental and control groups in case of IQ and gender was not possible.

Conclusion

According to the research results, we can conclude that the central auditory processing rehabilitation program is effective in improving the central auditory processing skill and it can also lead to the improvement of speech in noise perception and dichotic listening of dyslexic students, and such improvements are stable. In other words, by reinforcing the direct auditory skills in the auditory training programs, one can improve the central auditory processing in both speech perception in noise and dichotic hearing. Using this program is suggested for dyslexic students with central auditory processing disorder.

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REFERENCES

1. Ramus F, Pidgeon E, Frith U. The relationship between motor control and phonology in dyslexic children. J Child Psychol Psychiatry. 2003;44(5):712-22.
2. Snowling MJ. Developmental dyslexia. Current Paediatrics. 2001;11(1):10-3.
3. Bretherton L, Holmes VM. The relationship between auditory temporal processing, phonemic awareness, and reading disability. J Exp Child Psychol. 2003;84(3):218-43.
4. Serniclaes W, Sprenger-Charolles L, Carré R, Demonet JF. Perceptual discrimination of speech sounds in developmental dyslexia. J Speech Lang Hear Res. 2001;44(2):384-99.
5. Griffiths YM, Snowling MJ. Auditory word identification and phonological skills in dyslexic and average readers. Appl Psycholinguist. 2001;22(3):419-39.
6. American Speech-Language-Hearing Association. 2005. (central) auditory processing disorders [Technical Report]. Available from www.asha.org/policy.
7. Boets B, Vandermosten M, Poelmans H, Luts H, Wouters J, Ghesquière P. Preschool impairments in auditory processing and speech perception uniquely predict future reading problems. Res Dev Disabil. 2011;32(2):560-70.
8. Kraus N. Auditory pathway encoding and neural plasticity in children with learning problems. Audiol Neurootol. 2001;6(4):221-7.
9. Cherry RS, Kruger B. Selective auditory attention abilities of learning disabled and normal achieving children. J Learn Disabil. 1983;16(4):202-5.
10. Amitay S, Ahissar M, Nelken I. Auditory processing deficits in reading disabled adults. J Assoc Res Otolaryngol. 2002;3(3):302-20.
11. Walker MM, Shinn JB, Cranford JL, Givens GD, Holbert D. Auditory temporal processing performance of young adults with reading disorders. J Speech Lang Hear Res. 2002;45(3):598-605.
12. Sharma M, Purdy SC, Kelly AS. Comorbidity of auditory processing, language, and reading disorders. J Speech Lang Hear Res. 2009;52(3):706-22.
13. Farmer ME, Klein RM. The evidence for a temporal processing deficit linked to dyslexia: A review. Psychon Bull Rev. 1995;2(4):460-93.
14. Bellis TJ. Historical foundations and the nature of central auditory processing disorder. In: Musiek FE, Chermak GD, editors. Handbook of central auditory processing disorders: volume 2: comprehensive intervention. 1st ed. San Diego: Plural Pub Inc; 2007. p. 119-36.
15. Bellis TJ. Developing deficit-specific intervention plans for individuals with auditory processing disorders. Semin Hear. 2002;23(4):287-96.
16. Fu QJ, Galvin J, Wang X, Nogaki G. Moderate auditory training can improve speech performance of adult cochlear implant patients. Acoust Res Lett Online. 2005;6(3):106-11.
17. Stacey PC, Summerfield AQ. Effectiveness of computer-based auditory training in improving the perception of noise-vocoded speech. J Acoust Soc Am. 2007;121(5 Pt1):2923-35.
18. Loeb DF, Gillam RB, Hoffman L, Brandel J, Marquis J. The effects of Fast ForWord Language on the phonemic awareness and reading skills of school-age children with language impairments and poor reading skills. Am J Speech Lang Pathol. 2009;18(4):376-87.
19. Given BK, Wasserman JD, Chari SA, Beattie K, Eden GF. A randomized, controlled study of computer-based intervention in middle school struggling readers. Brain Lang. 2008;106(2):83-97.
20. Moossavi A, Mehrkian S, Lotfi Y, Faghihzadeh S, Sadjedi H. The effect of working memory training on auditory stream segregation in auditory processing disorders children. Iranian Rehabilitation Journal. 2015;13(1):22-7.
21. Malayeri S, Lotfi Y, Moossavi SA, Rostami R, Faghihzadeh S. Brainstem response to speech and non-speech stimuli in children with learning problems. Hear Res. 2014;313:75-82.
22. Delavar A. Theoretical and practical research in the humanities and social sciences. 2nd ed. Tehran: Roshd; 2015. Persian.
23. Strange AK, Zalewski TR, Waibel-Duncan MK. Exploring the usefulness of Fisher's auditory problems checklist as a screening tool in relationship to the buffalo model diagnostic central auditory processing test battery. J Educ Audiol. 2009;15:44-52.
24. Shayanmehr S, Tahaei AA, Fatahi J, Jalaie S, Modarresi Y. Development, validity and reliability of Persian quick speech in noise test with steady noise. Aud Vest Res. 2015;24(4):234-44.

25. Guenette LA. How to administer the dichotic digit test. Hear J. 2006;59(2):50.
26. Nejati V, Alipour F, Jalilvand Karimi L, Esfandiari L. Persian version of the dichotic digit test for children: design and evaluation of the psychometric properties. Aud Vest Res. 2016;25(1):55-62.
27. Bakker DJ, Van der Vlugt H, Claushuis M. The reliability of dichotic ear asymmetry in normal children. Neuropsychologia. 1978;16(6):753-7.
28. Shafiei B, Tavakol S, Alinia L, Maracy MR, Sedaghati L, Foroughi R. Developing a screening inventory reading test (IRT) for the Isfahanian students of the first to fifth grade. Audiol. 2009;17(2):53-60. Persian.
29. Bellis TJ. Treatment of (central) auditory processing disorders. In: Valente M, Hosford-Dunn H, Roeser RJ, Galster JA, editors. Audiology: treatment. 2nd ed. New York: Thieme Medical Publishers, Inc; 2008. p. 271-92.
30. Pokorni JL, Worthington CK, Jamison PJ. Phonological awareness intervention: comparison of Fast ForWord, Earobics, and LiPS. J Educ Res. 2004;97(3):147-58.
31. Miller CA, Uhring EA, Brown JJC, Kowalski EM, Roberts B, Schaefer BA. Case studies of auditory training for children with auditory processing difficulties: a preliminary analysis. Contemp Issues Commun Sci Disord. 2005;32:93-107.
32. Thibodeau LM. Computer-based auditory training (CBAT) for (central) auditory processing disorder. In: Chermak G, Musiek F, editors. Handbook of central auditory processing disorder: comprehensive intervention, Vol II. 1st ed. San Diego: Plural Publishing; 2007. p. 167-206.
33. Boothroyd A. Developments in speech audiometry. In: Bess FH, Gravel JS, editors. Foundations of pediatric audiology. San Diego: Plural Publishing; 2006. p. 121-6.
34. Deppeler JM, Taranto AM, Bench J. Language and auditory processing changes following Fast ForWord. Australian and New Zealand Journal of Audiology. 2004;26(2):94-109.
35. McArthur GM, Ellis D, Atkinson CM, Coltheart M. Auditory processing deficits in children with reading and language impairments: can they (and should they) be treated?. Cognition. 2008;107(3):946-77.